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ORIGINAL PAPER

Exposure to sunlamps, tanning beds, and melanoma risk

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Abstract
Objective To estimate the separate effects of sunlamp and tanning bed device use on melanoma risk.
Methods Population-based case–control study of 423 cases of melanoma and 678 controls in the state of New Hampshire. Exposure data, including sunlamp and tanning bed use, were collected by telephone interview. Associations were evaluated using logistic regression analyses.
Results About 17% of participants ever used a sunlamp, and most use (89%) occurred before 1980. The OR was 1.39 (95% CI 1.00–1.96) for ever using a sunlamp, 1.23 (95% CI 0.81–1.88) for those starting sunlamp use <20 years, and 1.71 (95% CI 1.00–2.92) for those starting ≥20 years. Data suggested increasing risk with number of sunlamp uses and with duration of use (tests of trend $p = 0.02$). The overall prevalence of tanning bed use was 22% and most use (83%) occurred after 1980. The OR was 1.14 (95% CI 0.80–1.61) for ever using a tanning bed; there was no evidence that risk increased with frequency or duration of use. The OR was 1.96 (95% CI 1.06–3.61) for having used both devices.
Conclusion Results suggest a modest association between sunlamp use and melanoma risk, and increasing risk with greater frequency and duration of use. No association with tanning bed use was found, but sufficient lag time may not have elapsed to assess a potential effect.

Keywords Melanoma · Skin cancer · Sunlamp · Tanning bed · Artificial UV

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Introduction

Over the last 25 years, cutaneous melanoma has become an increasingly common cause of cancer morbidity and mortality in Caucasian populations worldwide [1–3]. The American Cancer Society estimates that melanoma will account for approximately 59,940 cases and 8,110 deaths in the United States during 2007 [4, 5]. The etiology of cutaneous melanoma is not completely understood, but evidence from numerous studies indicates that host factors, including hair and eye color, nevi, and sensitivity to the sun are related to risk [1, 6–12].

Although much remains to be learned about the type, periodicity, and timing of sun exposure, UV radiation is clearly the predominant environmental, and thus potentially modifiable risk factor for melanoma [13]. Historically, UVB has been thought to account for most of the risk [14–18]. UVB varies considerably in intensity with greatest emission near the equator, and the least near the poles, a pattern corresponding roughly to variation in melanoma incidence [19, 20]. UVA varies much less significantly with latitude. A role for UVA is indicated by studies showing melanomas arising in those who receive UVA for treatment of dermatologic conditions [21–23] as well as by basic scientific evidence of the harmful effects of UVA on DNA, cells, and animals [18].

The influence of artificial sources of UV on risk of melanoma has been examined by numerous studies (for example [24–28]) although findings to date have been heterogeneous, with much of the inconsistency attributed to small sample sizes with low statistical power to detect a plausible association [7, 25–27, 29–39]. Moreover, most studies to date have not been able to distinguish exposures by device type and many did not control for known melanoma risk factors such as pigmentary characteristics and solar exposures [29, 37, 40]. Despite the possibility of increased skin cancer risk, the use of tanning devices is popular among youth, [41, 42] and the demand for tans has produced an exponential growth of tanning facilities in recent years [43, 44]. According to the media, more than a million people daily use tanning beds in the US, [45, 46] and it is estimated that there are 28 million users of tanning facilities and 50,000 tanning facilities nationwide.[43] Modern tanning beds (post-1980) use fluorescent bulbs that emit mostly UVA and smaller than past UVB doses [29, 47, 48]. They deliver up to three times the UVA dose of that delivered by natural sunlight and a UVB dose rate that can approach the rate of bright sunlight [44].

In the modern era, when public health campaigns advocate minimizing or avoiding sun exposure, [5, 49–55] the potential influence of artificial UV sources on melanoma risk is worrisome. The objective of this research was to estimate the association between melanoma risk and use of two types of UV-emitting devices: sunlamps (used mostly pre-1980; higher UVB content) and tanning beds (used mostly post-1980; higher UVA content) while adjusting for a comprehensive vector of melanoma risk factors. Before conducting the present analyses, tanning device use was hypothesized to be associated with an increased risk of melanoma when compared with non–users, adjusting for host characteristics and solar exposures.

Materials and methods

This study was approved by the Committee for the Protection of Human Subjects at Dartmouth College. All participants gave verbal consent for the interview and signed consent for the skin examination and for the release of pathology records.

The methods of this study have been described previously [11]. Case subjects of ages 20 through 69 with a diagnosis of cutaneous malignant melanoma (hereafter referred to as melanoma) occurring between January 1995 and December 1998 were ascertained through the New Hampshire (NH) State Cancer Registry. Those potentially eligible for study enrollment were NH residents with a working telephone number who were able to participate in an interview conducted in English. We sent a letter to the physician of record requesting permission to contact the patient. If an objection was not received within a month, a letter introducing the study was mailed to the case subject, followed within 2 weeks by a telephone call from the interviewer. Using this approach, we enrolled 444 of 579 (77%) potentially eligible cases; 15 (3%) were excluded at their physician's request, 26 (4%) could not be reached, 30 (5%) had died, and 64 (11%) declined to participate. Twenty-one enrolled cases were deemed ineligible; of these, seven had a previous diagnosis of melanoma, four had an unknown primary site, two had tumors of acral lentiginous histology, and for eight persons the diagnosis of melanoma was not definitive. Thus, 423 cases of first primary melanoma were available for analysis.

Control subjects were ascertained from lists of licensed drivers obtained through the NH Department of Motor Vehicles, and were selected at random to achieve a gender and age (in 5-year age groups) distribution similar to that of case subjects. Controls were also selected to achieve a control:case ratio of 1.6 to allow separate studies of atypical moles within the control group. Potentially eligible control subjects were NH residents with a working telephone, and able to participate in an English-speaking interview. A letter introducing the study was sent to potential control participants, followed within 2 weeks by a telephone call from the interviewer. We enrolled 684 of 1121 (61%) potentially eligible control subjects; 87 (8%) could not be reached, 13 (1%) controls had died, and 337 (30%) declined to participate. Of the 684 control participants, six were deemed ineligible due to a prior diagnosis of melanoma. Thus, 678 controls were available for analysis.

The 40-min telephone interview queried participants for demographic factors, pigmentary characteristics, episodes of sunburn, sun exposure, and use of tanning beds or sunlamps. The details of the questionnaire have been described elsewhere [11]. Briefly, we asked participants to report eye color, natural hair color at age 20, and the reaction of their skin to strong summer sun exposure. Sunburns were assessed separately as episodes of peeling sunburn and blistering sunburn in 10-year age periods starting at age 10. Sun exposure was assessed by asking participants to report outdoor occupational and recreational activities, and sunbathing, defined as relaxing in the sun.

Information regarding sunbathing was captured for 10-year age periods starting at age 10; outdoor occupations were assessed starting at age 6 (to accommodate farm work). We queried participants for 11 standard outdoor recreational activities, and an unlimited number of "other activities," starting at age 10. For all three variables, hours of sun exposure were capped at 10 h per day. Sun exposure variables were derived as cumulative exposures (total hours exposed) for each sun exposure type (recreational, sunbathing, and occupational) and a combined total sun exposure category. Each variable was assessed within life periods categorized as childhood ($\leq$20 years), adulthood ($\geq$20 years), and lifetime (total). Participants were also asked to report their use of sunlamps and tanning beds separately, by answering yes or no to the following questions: "Have you ever used a sunlamp?" or "Have you ever gone to a tanning salon or used a tanning bed?" For each exposure subjects were asked the total number of times the device was used, the age of first use, and the age of last use. No differentiations for medical use or pictures of device types were used to prompt the responders. All exposures were assessed up until the reference date. The reference date was 1 year prior to the date of diagnosis for cases, and randomly assigned to controls based on the frequency of diagnosis dates in the case group.

We first examined descriptive statistics (univariate, proportion, and frequency) on all study variables. All bivariate relations were examined using Pearson or Spearman correlations and chi-square tests. Exposure variables were initially examined in age- and gender-adjusted logistic models of melanoma risk. The final subset of confounders was selected by the model building strategy based on effect changes described by Greenland [56]. Briefly, potential confounders were variables that, when added to age- and sex-adjusted models of melanoma risk, changed the OR of the exposures of interest (sunlamp, tanning bed use) more than 10%. Highly correlated variables were not included simultaneously in the models. When variables were correlated, the final models contained the term for the stronger confounder. The stronger confounder was determined by the magnitude of change in the OR corresponding to the exposure of interest when the variable was added to the logistic model and by the strength of its association with melanoma and the exposures of interest. In the models, continuous variables were initially in quintiles and combined when appropriate to avoid sparsely populated categories. Odds ratios (OR) and 95% confidence intervals (CI) were computed from logistic regression models to examine the influence of sunlamp or tanning bed use on melanoma risk. Tests for trend were based on the categories shown and conducted using the z-statistic defined as the beta coefficient divided by its standard error. Effect measure modification between sunlamps/tanning beds and other variables (e.g., age and pigmentary characteristics) was analyzed using stratification and the Breslow-Day test for homogeneity of ORs. All statistical analyses were conducted in SAS and all p values were based on two-sided tests [57].

Results

Table 1 shows the characteristics of the study population by case–control status. Cases and controls were comparably distributed by age and gender, reflecting the matching scheme. The majority of participants (77.2%) were married; cases had slightly more education than controls, and nearly half of all participants had at least a college education. As expected, blue eye color was more common in the cases (46.6% vs. 34.8%), and brown eye color was more common in the controls (34.6% vs. 23.0%). Red or blonde hair color was more common among the cases, whereas brown, dark-brown, and black were more common in the controls. In response to strong summer sun, a higher proportion of cases reported burning without tanning 48.2% vs. 42.2%), whereas a higher proportion of controls tanned without burning (10.0% vs. 3.3%).

Sunlamp use

Overall, 17.1% of study participants (20.3% of cases, 15.0% of controls) reported ever using a sunlamp. The average age of first use was 20 years for cases and controls. Virtually all sunlamp use (89%) occurred before 1980 (Fig. 1). We found little evidence that the association between sunlamp use and melanoma risk was confounded by measured covariates (Table 2). The covariate-adjusted OR for ever use of a sunlamp was 1.39 (95% CI 1.00–1.96) overall. Of those who used sunlamps, 61.2% of cases and 66.3% of controls did so before age 20. The covariate-adjusted OR was 1.23 (95% CI 0.81–1.88) for those starting use before age 20, and 1.71 (95% CI 1.00–2.92) for those starting use after age 20. Based on the cutpoints shown, the data suggested an increasing risk with the number of times used (test of trend $p = 0.02$). Relative to never use, the adjusted OR was 1.29 (95% CI 0.84–1.99) for use less than 6 times, and 1.54 (95% CI 0.93–2.57) for use 6 or more times. A greater duration of use (years elapsed between last and first use) ($\leq$1, >1) was also associated with an increased melanoma risk (test of trend $p = 0.02$); the OR for >1 year of use was 1.57 (95% CI 0.91–2.71). Although the estimates were imprecise, the data suggested an elevated risk for those who last used a sunlamp 15 or more years earlier, although the findings were not of statistical significance. The ORs were 1.53 (95% CI 0.84–

Table 1 Characteristics of the study population by case and control status

	Case $n = 423$ n (%)	Control $n = 678$ n (%)	OR_{crude} (95% CI)
Gender			
Female	200 (47.3)	330 (48.7)	
Male	223 (52.7)	348 (51.3)	
Age			
20–29 years old	22 (5.2)	26 (3.8)	
30–39	72 (17.0)	132 (19.5)	
40–49	97 (22.9)	134 (19.8)	
50–59	117 (27.7)	197 (29.0)	
60–69	115 (27.2)	189 (27.9)	
Mean age (±SD)	50.1 (±12.2)	50.3 (±11.6)	
Educational Level			
Completed school through grade 8	20 (4.7)	35 (5.2)	1.0
Completed high school	144 (34.1)	261 (38.6)	0.97 (0.54–1.74)
Completed college (2-year degree)	74 (17.5)	127 (18.8)	1.02 (0.55–1.90)
Completed college (4-year degree)	115 (27.3)	157 (23.2)	1.28 (0.70–2.34)
Completed graduate or professional school	69 (16.4)	96 (14.2)	1.26 (0.67–2.40)
Marital Status			
Married	329 (78.3)	517 (76.3)	1.13 (0.84–1.50)
Not married	91 (21.7)	161 (23.7)	
Family history of melanoma			
Yes	98 (23.2)	131 (20.2)	1.25 (0.93–1.70)
No	320 (76.8)	535 (79.8)	
Pigmentary characteristics			
Eye color			
Brown	97 (23.0)	234 (34.6)	1.0
Blue	196 (46.6)	235 (34.8)	2.01 (1.49–2.70)
Green/gray/hazel	128 (30.4)	207(30.6)	1.50 (0.93–2.50)
Hair color age 20 years			
Brown/dark brown/black	203 (47.7)	410 (60.6)	1.0
Reddish blond/strawberry blond	19 (4.5)	13 (1.9)	5.52 (1.99–15.30)
Red	17 (4.0)	13 (1.9)	4.94 (1.76–13.80)
Blond	43 (10.2)	39 (5.8)	4.13 (1.80–9.80)
Light brown/dark blond	123 (29.1)	172 (25.4)	2.70 (1.25–5.80)
Red-brown or auburn	19 (4.5)	30 (4.4)	2.39 (0.94–6.08)
Freckles			
Yes	302 (73.1)	358 (52.8)	2.31 (1.77–3.01)
No	114 (26.9)	312 (47.2)	
Sun sensitivity-acute exposure			
Tan without sunburn	14 (3.3)	68 (10.0)	1.0
Sunburn w/peeling, no tan	204 (48.2)	282 (42.2)	3.51 (1.90–6.42)
Sunburn with peeling and freckles, no tan	20 (4.7)	42 (6.2)	2.31 (1.10–5.10)
Sunburn followed by tan	185 (43.8)	286 (41.6)	3.14 (1.70–5.75)
Sunburn history			
Childhood sunburn with peeling			
Never	32 (7.7)	95(14.3)	1.0
Low	195 (47.1)	323 (48.6)	1.79 (1.16–2.78)
High	187 (45.2)	246 (37.1)	2.26 (1.45–3.51)

Table 1 continued

	Case $n = 423$ n (%)	Control $n = 678$ n (%)	OR_{crude} (95% CI)
Adult sunburn with peeling			
Never	74 (18.1)	122 (18.4)	1.0
Low	156 (38.0)	284 (42.8)	0.91 (0.63–1.28)
High	180 (43.9)	258 (38.8)	1.15 (0.81–1.62)
Lifetime sunburn with peeling			
Never	6 (1.5)	36 (5.5)	1.0
Low	194 (47.8)	323 (49.2)	3.60 (1.49–8.70)
High	206 (50.7)	297 (45.3)	4.16 (1.68–10.11)
Childhood sunburn with blistering			
Never	198 (47.5)	393 (58.2)	1.0
Low	121 (29.0)	160 (23.7)	1.50 (1.12–2.01)
High	98 (23.5)	122 (18.1)	1.59 (1.16–2.19)
Adult sunburn with blistering			
Never	260 (62.9)	443 (66.5)	1.0
Low	92 (22.3)	149 (22.4)	1.05 (0.78–1.42)
High	61 (14.8)	74 (11.1)	1.41 (1.00–2.03)
Lifetime sunburn with blistering			
Never	144 (35.1)	286 (43.0)	1.0
Low	130 (31.7)	221 (33.2)	1.17 (0.89–1.61)
High	136 (33.2)	158 (23.8)	1.71 (1.28–2.32)
Solar exposure history			
Total childhood solar exposure			
None	8 (1.9)	11 (1.7)	1.0
Low	181 (44.6)	340 (51.9)	0.73 (0.29–1.85)
High	217 (53.5)	304 (46.4)	0.98 (0.37–2.48)
Total adulthood solar exposure			
None	0 (0)	0 (0)	–
Low	180 (45.6)	337 (52.5)	1.0
High	214 (54.4)	295 (47.5)	1.36 (1.11–1.72)
Total lifetime solar exposure			
None	0 (0)	0 (0)	–
Low^{ref}	175 (45.0)	333 (53.1)	1.0
High	214 (55.0)	294 (46.9)	1.39 (1.07–1.79)
Recreational childhood solar exposure			
None	46 (11.1)	82 (12.4)	1.0
Low	166 (40.2)	307 (46.5)	0.96 (0.64–1.44)
High	201 (48.7)	271 (41.1)	1.32 (0.88–1.98)
Recreational adulthood solar exposure			
None	8 (1.9)	13 (2.4)	1.0
Low	194 (47.0)	329 (50.1)	1.18 (0.50–2.81)
High	211 (51.1)	312 (47.5)	1.35 (0.57–3.22)
Recreational lifetime solar exposure			
None	0 (0)	0 (0)	–
Low	187 (45.3)	348 (53.0)	1.0
High	226 (54.7)	309 (47.0)	1.36 (1.06–1.74)

Table 1 continued

	Case $n = 423$ n (%)	Control $n = 678$ n (%)	OR_{crude} (95% CI)
Occupational childhood solar exposure			
None	196 (46.3)	314 (46.3)	1.0
Low	117 (27.7)	179 (26.4)	1.05 (0.78–1.40)
High	110 (26.0)	185 (27.3)	0.95 (0.71–1.28)
Occupational adulthood solar exposure			
None	272 (64.3)	458 (67.8)	1.0
Low	74 (17.5)	115 (17.0)	1.08 (0.78–1.51)
High	77 (18.2)	103 (15.2)	1.26 (0.90–1.78)
Occupational lifetime solar exposure			
None	160 (37.8)	266 (29.4)	1.0
Low	136 (32.2)	211 (31.2)	1.07 (0.80–1.43)
High	127 (30.0)	199 (39.4)	1.06 (0.79–1.42)
Sunbathing childhood solar exposure			
None	143 (34.4)	232 (34.5)	1.0
Low	133 (32.0)	226 (33.6)	0.96 (0.71–1.29)
High	140 (33.6)	215 (31.9)	1.06 (0.78–1.42)
Sunbathing adulthood solar exposure			
None	115 (28.5)	208 (31.8)	1.0
Low	143 (35.4)	224 (34.4)	1.16 (0.84–1.57)
High	146 (36.1)	221 (33.8)	1.20 (0.88–1.63)
Sunbathing lifetime solar exposure			
None	90 (22.6)	150 (23.1)	1.0
Low	152 (38.1)	252 (38.9)	1.01 (0.72–1.40)
High	157 (39.3)	246 (38.0)	1.06 (0.77–1.48)

2.81) and 1.38 (95% CI 0.90–2.12) respectively for 15–24 and ≥25 years since last use, compared to never use.

Analyses stratified on age groups (20–29, 30–39, 40–49, 50–59, and 60–69) suggested that melanoma risk was not uniform across age groups (data not shown). In particular, the effect of ever sunlamp use appeared to be most pronounced in the 40–49 and 50–59 year age groups; OR = 1.42 (95% CI 0.75–2.71) and 2.47 (95% CI 1.40–4.38), respectively. However, Breslow-Day tests for homogeneity of the odds ratios indicated that the differences in effects stratified across 10-year age groups for all sunlamp exposures were not statistically significant ($p \geq 0.10$).

Additional analyses failed to show an association between sunlamp use and the site of the melanoma. We also found no evidence that the relationship between sunlamp use was modified by the host characteristics (eye color, hair color, sun sensitivity); all p values were ≥0.30.

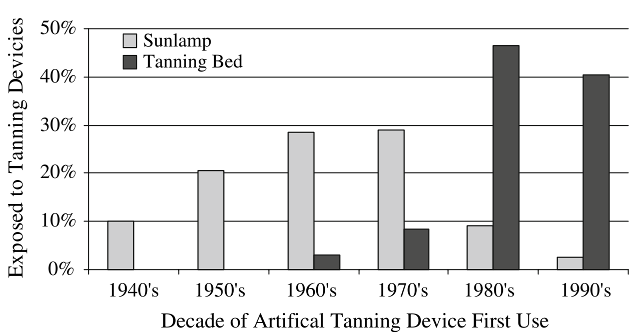

Fig. 1 Prevalence of exposure to artificial tanning devices according to device type and decade of first use in a population based, case–control study of incident cutaneous melanoma in New Hampshire between 1995 and 1998

Tanning bed use

Overall, 21.9% of study participants (22.9% of cases, 20.9% of controls) reported ever using a tanning bed. The average age of first use was 33 overall, 33 for cases, and 34 for controls. Most use of tanning beds occurred after 1979 (Fig. 1). The data suggested minimal confounding of frequency and duration of use by measured covariates. The covariate-adjusted OR for ever using a tanning bed was 1.14 (95% CI 0.80–1.61) overall (Table 2). Of those who used tanning beds, 18.6% of cases and 12.1% of controls reported first using a tanning bed before age 20. The covariate-adjusted OR was 1.78 (95% CI 0.76–4.15) for those starting use before age 20, and 1.08 (95% CI 0.75–1.55) for those

Table 2 Odds ratios (OR) and 95% confidence intervals (CI) for sunlamp and tanning bed use in relation to melanoma

	Case n (%)	Control n (%)	OR* (95% CI)	OR** (95% CI)	p value Test of trend
Sunlamp					
Sunlamp use					
Never	337 (79.7)	576 (85)	1.00	1.00	
Ever	86 (20.3)	102 (15.0)	1.46 (1.06–2.01)	1.39 (1.00–1.96)	
Age at first use					
Never	337 (79.9)	576 (85.1)	1.00	1.00	$p = 0.05$
<20	52 (12.3)	67 (9.9)	1.34 (0.91–1.98)	1.23 (0.81–1.88)	
≥20	33 (7.8)	34 (5.0)	1.70 (1.03–2.80)	1.71 (1.00–2.92)	
Frequency of use					
Never	337 (79.9)	576 (85.1)	1.00	1.00	$p = 0.02$
<6 times	52 (11.6)	67 (9.4)	1.33 (0.89–1.98)	1.29 (0.84–1.99)	
≥6 times	33 (8.5)	34 (5.5)	1.69 (1.05–2.73)	1.54 (0.93–2.57)	
Years of use					
Never	337 (79.9)	576 (85.1)	1.00	1.00	$p = 0.02$
≤1 year	55 (13.0)	67 (9.9)	1.42 (0.97–2.08)	1.30 (0.86–1.98)	
>1 year	30 (7.1)	34 (5.0)	1.55 (0.93–2.59)	1.57 (0.91–2.71)	
Years since last use					
Never	337 (79.9)	576 (85.1)	1.00	1.00	$p = 0.07$
<15	7 (1.7)	13 (1.9)	0.92 (0.36–2.32)	1.10 (0.42–2.96)	
15–24	25 (5.9)	27 (4.0)	1.58 (0.90–2.78)	1.53 (0.84–2.81)	
≥25	53 (12.6)	61 (9.0)	1.53 (1.03–2.27)	1.38 (0.90–2.12)	
Tanning bed					
Tanning bed use					
Never	326 (77.1)	536 (79.1)	1.00	1.00	
Ever	97 (22.9)	142 (20.9)	1.15 (0.83–1.58)	1.14 (0.80–1.61)	
Age at first use					
Never	326 (77.1)	536 (79.2)	1.00	1.00	
<20	18 (4.3)	17 (2.5)	1.89 (0.90–3.97)	1.78 (0.76–4.15)	
≥20	79 (18.6)	124 (18.3)	1.07 (0.78–1.51)	1.08 (0.75–1.55)	$p = 0.65$
Frequency of use					
Never	326 (77.1)	536 (79)	1.00	1.00	$p = 0.42$
<10 times	43 (10.2)	78 (12)	0.93 (0.62–1.41)	1.05 (0.67–1.64)	
≥10 times	54 (12.7)	63 (9)	1.46 (0.96–2.21)	1.25 (0.79–1.98)	
Years of use					
Never	326 (77)	536 (79.2)	1.00	1.00	$p = 0.49$
≤1 year	50 (12)	79 (11.5)	1.06 (0.72–1.68)	1.17 (0.76–1.79)	
>1 year	47 (11)	62 (9.3)	1.28 (0.83–1.98)	1.09 (0.68–1.76)	
Years since last use					
Never	326 (77.1)	536 (79.2)	1.00	1.00	$p = 0.50$
<15	89 (21.0)	127 (18.8)	1.18 (0.85–1.66)	1.15 (0.79–1.66)	
≥15	8 (1.9)	14 (2.0)	0.95 (0.40–2.30)	1.06 (0.42–2.66)	
Combined device use					
Either sunlamp or tanning bed use					
Never	156 (37.1)	218 (32.0)	1.0	1.0	
Ever	267 (63.2)	460 (68.1)	1.27 (0.97–1.71)	1.22 (0.83–1.80)	

Table 2 continued

	Case n (%)	Control n (%)	OR* (95% CI)	OR** (95% CI)	p value Test of trend
Both sunlamp and tanning bed use					
Never	267 (63.1)	460 (67.9)	1.00	1.00	
Ever	27 (6.4)	26 (3.8)	1.84 (1.05–3.25)	1.96 (1.06–3.61)	

*OR adjusted for age and gender

**OR adjusted for age, gender, family history of melanoma, hair color, freckles, sun sensitivity, total sun exposure hours

starting at age 20 or older. Based on the cut-points shown, there was no evidence that melanoma risk increased with either the number of episodes of tanning bed use (<10, ≥10), or the duration of use in years (≤1, >1). There was also no indication that time since last tanning bed use (<15, ≥15 years) was associated with an increased melanoma risk, and numbers were sparse in the latter grouping.

We conducted extensive sub-analyses according to the era and decade of tanning bed use (exposure before or after 1980), and by age of use. Aside from increased imprecision, the results were similar by strata corresponding to era or decade of use. In analyses stratified by age (in 10-year age-groups), the OR for ever use was highest in the 60–69-year age-group [1.56 (95% CI 0.66–3.66)]. However, we found no statistical evidence of heterogeneity of odds ratios across the 10-year age strata for any of the tanning bed exposures, including ever use (Breslow-Day test of homogeneity $p \geq 0.20$).

We found no association between tanning bed use and the site of the melanoma tumor. There was also no evidence of effect modification by pigmentary characteristics (eye color, hair color, sun sensitivity, $p \geq 0.25$).

Any device use and combined device use

Approximately one-third of both cases and controls reported using either a sunlamp or a tanning bed; the covariate-adjusted OR for use of either device was 1.22 (95% CI 0.83–1.80). Only 6.4% of cases and 3.8% of controls had used both sunlamps and tanning beds. When use of both UV devices was combined into one exposure variable, the covariate-adjusted OR was 1.96 (95% CI 1.06–3.61). The data provided no indication of increasing risk with either the frequency of use, or duration of use of both types of UV device combined. (data not shown)

Discussion

Although UV radiation from the sun is an accepted risk factor for all types of skin cancers, the evidence is far less clear for UV produced from artificial sources. Our findings support an association between sunlamp use and melanoma risk. Because sunlamps emit predominantly UVB, [47] which is known to increase skin cancer risk, this association is not surprising. Our findings also suggest that melanoma risk increases with more frequent and a longer duration of sunlamp use, although most use was over a short time period (on average less than 3 years). Consistent with a latency period of tumor development, risk appeared to be elevated for those who last used a sunlamp at least 15 years earlier, but not for those who discontinued use within the preceding 14 years.

We did not find evidence of an association between tanning bed use, which occurred mainly after 1980 in this study population, and melanoma risk. Modern tanning beds emit predominantly UVA, which may have less influence than UVB on melanoma risk [25, 29, 40, 47]. However, the global distribution of UVA radiation is associated with melanoma mortality rates, [14] medical use of UVA has shown an increase in skin cancers including melanoma, [23] and laboratory studies show that UVA can induce DNA damage in cells and melanoma precursors in animals [18]. In our study, tanning bed users started use later (33 vs. 20 years), and most use had occurred less than 20 years before the melanoma diagnosis date. Thus, tumor-induction time may have been insufficient, resulting in an underestimate of the association between tanning bed use and melanoma risk. This possibility is supported by Stern et al. who found that melanomas associated with UVA treatment of dermatologic conditions appeared to have a latency of at least 10–15 years [18, 23, 58]. Also, the most recent meta-analyses concluded that exposure at younger ages to tanning devices may have the biggest impact on melanoma risk, whereas in our study less than 15% of tanning bed users started use before the age of 20 [25, 29].

Similar to Chen et al. the strongest association was seen in subjects reporting use of both sunlamps and tanning beds. We explored the possibility this might be explained by the overall increased 'sun-seeking' behaviors among individuals that used both devices, but found no correlation between sun exposures and use of both devices, or with duration of use. Thus, it is possible the increased odds, although mainly arising from sunlamp exposures, may reflect the increased overall artificial UV exposure. Of course it is also possible the larger OR may be the result of small numbers or simply an artifact, which we were unable to assess.

A number of epidemiologic investigations have attempted to determine the nature of the putative association between artificial UV and melanoma with more recent studies generally suggesting use of artificial tanning devices is a risk factor [25, 28, 29]. However, three recent European studies reported conflicting results; the U.K. and multi-center European case–control studies found no association and the only cohort study to date in Scandinavia found the highest association among the youngest users with the longest lag time [26, 32, 59]. The difference in findings may be due to insufficient differentiation by device type, era of use, age at use of device type (i.e., not accounting for greater lag-time and use of devices with higher UVB-emissions) in the case–control studies. As with our findings the authors and reviewers of the Scandinavian study suggested that the increased risk was likely due to use of devices with higher UVB-emission and sufficient lag time to melanoma development. Swerdlow et al.'s 1998 review of the epidemiologic literature concluded there is insufficient evidence to determine whether or not tanning devices cause melanoma [37]. However, more recent meta-analyses by Gallagher et al. and the IARC identified a modestly increased risk of melanoma related to ever using a tanning device, despite between-study significant heterogeneity. Control for sun exposure, differentiation of device type, and era of use was not possible in most of the studies they assessed [25, 29]. Our findings, which allowed adjustment for solar exposures and differentiation of era of use, support the association with sunlamp use but are inconclusive for tanning bed use.

If an association between tanning bed use and melanoma risk is established, our data suggest the consequences at the population level may be greater than those for sunlamp use. Compared to sunlamp use, a slightly larger proportion of individuals reported using tanning beds, first used them at a younger age, used them more frequently and for a longer duration. Also, tanning bed use continues to gain popularity especially among teenagers and young adults, whereas sunlamps are largely of the past [41, 43, 44, 46, 48].

Strengths of the study include the amount of information available to assess tanning device use and adjust for a robust set of covariates. Many previous studies used only ever/never exposure categories and potential confounders, such as sun exposure, sun sensitivity, and socioeconomic status, were often not included in the previous analyses [28, 37, 46]. We were able to assess the frequency and duration of tanning device use, along with age at first use and time since last use. We were also able to adjust for a comprehensive vector of potential confounders and to conduct exploratory analyses involving sun exposures and sunburn histories. The latter analyses showed no correlation between combined device use and sun-exposure variables, reducing the likelihood that sunlamp or tanning bed use is a marker of sun-seeking behaviors [60]. The sunburn histories were also similar for users versus nonusers of tanning devices. However, differences in sun exposure histories did exist with tanning device non-users typically having the greatest number of hours of sun exposure.

There are several limitations of this research. Participants were retrospectively interviewed to obtain self-reported artificial tanning device use and other covariates, including solar exposures. We cannot exclude the possibility of recall bias, and in particular, cases might be more likely than controls to report exposures. It seems unlikely, however, that recall bias would affect self-reported sunlamp use without similarly affecting self-reported tanning bed use. It is conceivable that there is a differential level of accuracy in the information provided because cases may be more likely to recall the actual details (frequency, duration, and age at use) of their exposure more accurately than controls. However, it seems unlikely that cases or controls would differentially or incorrectly report ever/never use of tanning devices. Because no preexisting records exist for tanning device use, there are no alternatives to the use of self-reported exposure data. It is conceivable that the small decrease in the OR when adjusted for covariates may be due to imprecise measurement. However, previous studies showed overall comparable small changes in effects from adjustments including solar exposures [26, 27, 33, 39, 61]. A potential limitation of our study is that the interview rate among the controls was lower than that in cases. If cases or controls that did not participate differed from interviewed subjects with regard to exposure history, then selection bias would be introduced. Unfortunately, no data on characteristics of non-participants was available.

As previously stated, we do not know the intensity or spectral outputs of the devices to which participants were exposed. Two recent studies have reported risk by detailed device type [32, 33]. Similar to Chen et al. but unlike Bataille et al. we found the strongest effect for sunlamp and combined device use rather than for tanning bed use [32, 33]. The nature of lamps and the type of use in the US (UVA-dominated versus UVB-dominated, commercial versus home) have changed over time [25, 29, 47]. Diffey and Farr showed that, since the mid-1980s, modern tanning devices available primarily in commercial settings use fluorescent bulbs that emit mostly UVA with smaller UVB doses [47]. In our study, most sunlamp exposures occurred before the changeover and most tanning bed exposures occurred afterward. Consequently, the association we observed with sunlamps probably reflects UVB exposure.

In an effort to compensate for the lack of detailed information about UV emissions in sunlamps and tanning beds, we examined both the decade of first use and the type of device used in relation to risk. Separating the device categories (sunlamp vs. tanning bed) in this study provided a proxy, although not perfect, for higher (sunlamp) and lower (tanning bed) ratios of UVB to UVA emission [27, 62, 63]. It would be difficult, if not impossible, in a retrospective study to collect detailed information on output spectra and intensity of devices because the technical features of tanning devices are variable and have changed over time. Another limitation of our study is that our duration measure, which was based on time of first and last use, is only a proxy for actual duration of use.

In summary, our results suggest an association between sunlamp use (higher UVB content) and melanoma risk, and an increasing risk with greater frequency and duration of use; sufficient lag time may not have elapsed to assess a potential effect of tanning bed use (higher UVA content). The dependent association between artificial UV and melanoma is complicated by the wide variety of emission spectra that characterize devices and lag time between device exposure and melanoma diagnosis. Prospective research designed to incorporate sufficient lag times as well as to examine the UV emissions of artificial tanning device exposures would provide critical information for understanding the potential relation of UVA to melanoma risk.

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